

## PATENT COOPERATION TREATY

PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner  
 US Department of Commerce  
 United States Patent and Trademark  
 Office, PCT  
 2011 South Clark Place Room  
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 in its capacity as elected Office

|  |  |
|--|--|
| Date of mailing (day/month/year)<br>10 November 2000 (10.11.00)        |  |
| International application No.<br>PCT/EP00/02364                        | Applicant's or agent's file reference<br>00 MR 22 E        |
| International filing date (day/month/year)<br>17 March 2000 (17.03.00) | Priority date (day/month/year)<br>25 March 1999 (25.03.99) |
| Applicant<br>PRETI, Franco et al                                       |  |

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:  
 11 October 2000 (11.10.00)

☐ in a notice effecting later election filed with the International Bureau on:  
 \_\_\_\_\_

2. The election ☒ was

☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

|   |  |
|---|--|
| The International Bureau of WIPO<br>34, chemin des Colombettes<br>1211 Geneva 20, Switzerland<br>Facsimile No.: (41-22) 740.14.35 | Authorized officer<br>Zakaria EL KHODARY<br>Telephone No.: (41-22) 338.83.38 |
|---|--|



# INTERNATIONAL SEARCH REPORT

International Application No.

T/EP 00/02364

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 C30B25/14 C23C16/44

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C30B C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                   | Relevant to claim No. |
|------------|--|-----------------------|
| A          | EP 0 415 191 A (LPE SPA)<br>6 March 1991 (1991-03-06)<br>cited in the application<br>figure 3<br>--- | 1, 11-15              |
| A          | DE 38 38 164 A (SUMITOMO CHEMICAL CO)<br>24 May 1989 (1989-05-24)<br>claim 1; figure 2<br>---        | 1                     |
| A          | EP 0 293 021 A (LPE SPA)<br>30 November 1988 (1988-11-30)<br>cited in the application<br>---         |                       |
|            | ---<br>-/-   |                       |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"S" document member of the same patent family

Date of the actual completion of the international search

26 July 2000

Date of mailing of the international search report

10/08/2000

Name and mailing address of the ISA  
European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
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Authorized officer

Cook, S



## INTERNATIONAL SEARCH REPORT

International Application No.

T/EP 00/02364

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
| A          | ELIJAH: "improving resistivity and thickness uniformity of epitaxial deposits"<br>IBM TECHNICAL DISCLOSURE BULLETIN,<br>XP002143460<br>NEW YORK US<br>the whole document<br>----- | 1                     |
| A          | EP 0 305 195 A (TEXAS INSTRUMENTS INC)<br>1 March 1989 (1989-03-01)<br>column 2, line 59 - line 61; figure 5<br>-----   | 1                     |



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

CT/EP 00/02364

| Patent document<br>cited in search report |   | Publication<br>date | Patent family<br>member(s)  | Publication<br>date  |
|---|---|---------------------|---|--|
| EP 0415191                                | A | 06-03-1991          | IT 1231547 B<br>JP 3116928 A  | 17-12-1991<br>17-05-1991   |
| DE 3838164                                | A | 24-05-1989          | JP 1125923 A<br>GB 2212173 A, B<br>US 4976216 A   | 18-05-1989<br>19-07-1989<br>11-12-1990   |
| EP 0293021                                | A | 30-11-1988          | IT 1215444 B<br>DE 3887002 D<br>DE 3887002 T<br>JP 2588578 B<br>JP 63284810 A<br>US 4858557 A | 14-02-1990<br>24-02-1994<br>28-04-1994<br>05-03-1997<br>22-11-1988<br>22-08-1989 |
| EP 0305195                                | A | 01-03-1989          | JP 1144617 A<br>JP 2882605 B  | 06-06-1989<br>12-04-1999   |





## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

|  |   |  |
|--|---|--|
| Applicant's or agent's file reference<br><b>00 MR 22 E</b> | <b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. |  |
| International application No.<br><b>PCT/EP 00/ 02364</b>   | International filing date (day/month/year)<br><b>17/03/2000</b>   | (Earliest) Priority Date (day/month/year)<br><b>25/03/1999</b> |
| Applicant<br><b>LPE SPA</b>                                |   |  |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

## 1. Basis of the report

- a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ Certain claims were found unsearchable (See Box I).

3. ☐ Unity of invention is lacking (see Box II).

## 4. With regard to the title,

☐ the text is approved as submitted by the applicant.

☒ the text has been established by this Authority to read as follows:

**REACTION CHAMBER FOR AN EPITAXIAL REACTOR**

## 5. With regard to the abstract,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

## 6. The figure of the drawings to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

1  
☐ Non of the figures.



## PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT 5


(PCT Article 36 and Rule 70)

|   |  |  |
|---|--|--|
| Applicant's or agent's file reference<br>00 MR 22 E                                       | <b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/PEA/416) |  |
| International application No.<br>PCT/EP00/02364   | International filing date (day/month/year)<br>17/03/2000   | Priority date (day/month/year)<br>25/03/1999 |
| International Patent Classification (IPC) or national classification and IPC<br>C30B25/14 |  |  |
| Applicant<br>LPE SPA  |  |  |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
- ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).
- These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

|   |   |
|---|---|
| Date of submission of the demand<br>11/10/2000  | Date of completion of this report<br>18.12.2000                   |
| Name and mailing address of the international preliminary examining authority:<br> European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Mauger, J<br>Telephone No. +49 89 2399 8447 |





## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP00/02364

### I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).):*

**Description, pages:**

1-12 as originally filed

**Claims, No.:**

1-15 as originally filed

**Drawings, sheets:**

1/4-4/4 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:



# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP00/02364

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

### 1. Statement

|                               |                  |
|-------------------------------|------------------|
| Novelty (N)                   | Yes: Claims 1-15 |
|                               | No: Claims       |
| Inventive step (IS)           | Yes: Claims 1-15 |
|                               | No: Claims       |
| Industrial applicability (IA) | Yes: Claims 1-15 |
|                               | No: Claims       |

2. Citations and explanations  
**see separate sheet**





**Re Item V**

**Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

- 1) Reference is made to the following document:

D1: EP-A-0 415 191 (LPE SPA) 6 March 1991 (1991-03-06) cited in the application

- 2) The present application defines a reaction chamber for an epitaxial reactor (claim 1).
- 3) The closest prior art is represented by document D1, which similarly discloses a reaction chamber for an epitaxial reactor. The reaction chamber comprises a bell jar which encloses a frustum pyramidal susceptor. The susceptor is provided with protrusions extending the length of the edges of the susceptor which serve to increase the uniformity of the gas flow in the reaction chamber. Reaction gas is fed to the reaction chamber by means of a circular diffuser disposed at the same height as the shoulder of the bell jar (see Figure 3 and column 4, lines 15 to column 6, line 20 and claims).
- 3.1) The present reaction chamber is notably novel because the diffuser has a different design, because the a plate used to deflect the flow of the gas is disposed at a height which corresponds to a cylindrical portion of the bell jar and because the projecting baffles on the corners of the susceptor do not extend the whole length of the susceptor. Thus the novelty of the subject-matter of present claims 1-15 can be recognised (Article 33(2) PCT).
- 4) The problem addressed by the present application is to provide a reaction chamber which is able to consistently provide high quality products over a long period of operation.

The design of the gas diffuser in document D1 and the fact that this diffuser distributes the gas at a height which corresponds to the shoulder of the bell jar in combination make the reaction chamber of document D1 very sensitive to small



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT - SEPARATE SHEET**

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International application No. PCT/EP00/02364

changes. In particular changes which occur at the end of each batch or when parts are replaced. Such small changes unpredictably alter the product quality. The present design of the diffuser, in combination with the location of the plate, and the short baffles mean that the present reaction chamber has a far more predictable behaviour. This ensures that high quality products can consistently be obtained.

There is no suggestion in D1 or in any of the other cited documents that the present combination of features solve the problem addressed in the application and thus an inventive step can be recognised for the subject-matter of claims 1-15 (Article 33(3) PCT).



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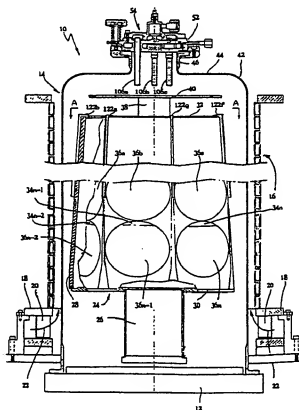
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

|   |           |  |
|---|-----------|--|
| <p>(51) International Patent Classification 7:<br/>C30B 25/14, C23C 16/44</p>   | <p>A1</p> | <p>(11) International Publication Number: <b>WO 00/58533</b><br/><br/>(43) International Publication Date: 5 October 2000 (05.10.00)</p>   |
| <p>(21) International Application Number: PCT/EP00/02364<br/><br/>(22) International Filing Date: 17 March 2000 (17.03.00)<br/><br/>(30) Priority Data:<br/>MI99A000607 25 March 1999 (25.03.99) IT<br/><br/>(71) Applicant (for all designated States except US): LPE SPA [IT/IT]; Via Dei Giovi, 7, I-20021 Bollate (IT).<br/><br/>(72) Inventors; and<br/>(75) Inventors/Applicants (for US only): PRETI, Franco [IT/IT]; Via San Benigno, 4, I-20133 Milano (IT). OGLIARI, Vincenzo [IT/IT]; Via Roma, 1/A, I-26010 Capergnanica (IT). TARENZI, Giuseppe [IT/IT]; Via Gramsci, 40, I-20072 Castiglione d'Adda (IT).<br/><br/>(74) Agents: MICHELOTTI, Giuliano et al.; Galleria San Babila, 4/C, I-20122 Milano (IT).</p> |           | <p>(81) Designated States: CN, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br/><br/>Published<br/><br/><i>With international search report.<br/>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p> |

(54) Title: REACTION CHAMBER FOR AN EPITAXIAL REACTOR

## (57) Abstract

Reaction chamber (10) for an epitaxial reactor comprising a belljar (14) made of insulating, transparent and chemically resistant material, a susceptor (24) provided with disk-shaped cavities (34a-n) for receiving wafers (36a-n) of material to be treated and having an insulating and chemically resistant plate (40) arranged above it, and a diffuser (54) consisting of a plurality of outlet pipes (106a-f) mounted on a cap (52) fixed to an upper opening (50) of the belljar (14).



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## REACTION CHAMBER FOR AN EPITAXIAL REACTOR

The present invention relates to an improvement to the reaction chamber of an epitaxial reactor performing deposition, by means of chemical vapour reaction, onto substrates of crystallized material. In particular, the present invention relates to an improved reaction chamber for an epitaxial reactor performing the deposition of semiconductor materials onto monocrystalline substrates made of the same materials and, more particularly, relates to the epitaxial growth by means of deposition of semiconductor silicon onto substrates of the same material.

The art involving the epitaxial growth of monocrystals on substrates consisting of the same material has been known for decades and is widely used for the preparation of electronic semiconductor devices and, in particular, for the preparation of silicon substrates or "wafers" to be used in the manufacture of integrated circuit chips.

For this silicon epitaxial growth, extensive use is made of chemical vapour deposition (CVD) obtained by means of the pyrolysis of gaseous compounds of silicon, called silicon source gases, such as silane ( $\text{SiH}_4$ ), monochlorosilane ( $\text{SiH}_3\text{Cl}$ ), dichlorosilane ( $\text{SiH}_2\text{Cl}_2$ ), trichlorosilane ( $\text{SiHCl}_3$ ) and silicon tetrachloride ( $\text{SiCl}_4$ ) in a hydrogen atmosphere. In order to achieve this pyrolysis, epitaxial reactors are used, said reactors being essentially formed by a belljar made of insulating and transparent material enclosing a support and a heater for silicon wafers, consisting of a susceptor made of graphite lined with silicon carbide and provided with substantially disk-shaped cavities receiving the silicon wafers and heated by means of the induction of currents therein by a coil externally embracing the quartz belljar. The susceptors may have various shapes, for example may be disk-shaped or in the form of a truncated pyramid, and here reference will be made to susceptors in the form of a truncated pyramid.

Reactors having a susceptor in the form of a truncated pyramid inside a quartz belljar have been known for a long time, as disclosed, for example, by Italian Patent No. 1,215,444 and by the corresponding European Patent No. 293,021.

In these types of reactors it was known that the speed of deposition of the

silicon onto a substrate, also made of silicon, more or less depended directly, all other conditions being equal, on the speed of flow of the abovementioned silicon source gases over the surfaces of the substrates kept at temperatures inducing pyrolysis of the said gases so as to form silicon deposits. As was commented in Italian Patent No. 1,231,547 and in the corresponding published application of European Patent No. 0,415,191 in the name of the owner of the present application, a truncated-pyramid susceptor enclosed in a cylindrical belljar having a hemispherical dome mounted above it produced flow speeds for silicon source gases which were minimal in the centre of the side faces of the susceptor, where the distance between the side faces and the neighbouring cylindrical belljar wall was greatest, and maximal close to corners separating adjacent faces of the susceptor, where the distance between said faces and said belljar wall was smallest. In order to overcome the corresponding variations in deposition speed and consequent variations in deposition thicknesses, in the abovementioned Italian Patent No. 1,231,547 it was thought to provide the corners of the susceptor with projections towards the belljar wall which would reduce to zero, or close to zero, the flow speeds of said gases in the vicinity of these projections and would render more or less uniform the speed across each face of the susceptor between said projections and the belljar wall. The projections formed for this purpose are shown in the abovementioned patent in Figures 8 to 19 which illustrate projections both inserted into the corners of the susceptor, as shown in Figures 8 to 9B, and formed from the same material of the susceptor, as shown in Figures 11 to 19. This system operated in a fairly satisfactory manner, although a certain degree of irregularity and unpredictability was noted with regard to operation when, for the purposes of cleaning or in order to repair serious faults, a belljar had to be replaced by a new one, even though it appeared to be practically identical to the one replaced. What is more, since the present tendency is to manufacture increasingly larger silicon wafers with a diameter of between about 100 mm (4") and 200 mm (8"), it was noted that these irregularities following replacement of the belljar were accentuated as increasingly larger silicon wafers were manufactured.

In this connection, it is already known that, when the diameter of the



wafers is increased, the qualitative requirements of the epitaxial wafers become increasingly stringent and, therefore, a reactor which simultaneously processes a large number of wafers (batch type reactor) must strike an acceptable balance between quantity and quality of the wafers produced (low cost).

A qualitative parameter of particular importance is the uniformity of thickness of the epitaxial layer deposited. In this connection, in an epitaxial reactor, in particular of the batch type, the uniformity of thickness is influenced by certain factors:

- difference in thickness between different points on each individual wafer;
- difference between individual wafers within the same batch;
- difference between various batches.

As can be seen from the abovementioned prior art documentation, the reaction chamber of a typical epitaxial reactor with a truncated-pyramid susceptor, known as a barrel epitaxial reactor, is essentially composed of the following parts:

- a cylinder-shaped belljar provided at the top with a flange connected to a belljar closing dome by a narrow cylindrical neck;
- a gas diffuser, to be used in the chemical vapour deposition reactions, consisting of an inlet pipe connected to two parallel plates having the function of distributing the outgoing gas flow in a uniform manner;
- a quartz plate to be rested on the cover of the susceptor; and
- a susceptor provided with its supports.

The components listed above together form the essential part of a reaction chamber.

It is known that the susceptors of reactors may receive numbers of wafers, depending on the diameter thereof, for example in accordance with the following table:

| Wafer diameter | No. of wafers | Wafer arrangement        |
|----------------|---------------|--------------------------|
| 100 mm (4")    | 30            | Three rings divided into |

| ten columns |    |   |
|-------------|----|---|
| 125 mm (5") | 24 | Three rings divided into<br>eight columns |
| 150 mm (6") | 14 | Two rings divided into<br>seven columns   |
| 200 mm (8") | 5  | One ring divided into<br>five columns     |

In general, the greater the number of rings, the smaller the number of columns and the greater the difficulty in achieving an acceptable balance in the uniformity of thickness of the epitaxial layers. The uniformity of thickness tends to vary greatly between rings, i.e. in a vertical direction, owing to the truncated-pyramid shape of the susceptor enclosed inside a substantially cylindrical belljar.

The reaction chamber, provided in accordance with the teachings of the abovementioned prior art, produces satisfactory results when all of its components are manufactured to the design specification. If, however, a component is not made to specification, serious drawbacks may arise. In general, neither the susceptor nor the quartz plate cause problems, unless there has been a major deviation. On the other hand, the belljar and the distributor are extremely critical and their critical nature increases with the production of wafers which have an increasingly larger diameter. This has resulted in the need for increasingly smaller tolerances which, at a certain point, become impossible to comply with, such that when a belljar or a diffuser - even when manufactured to the same design specification - is replaced, the results in terms of uniformity of thickness of the deposited layer vary greatly, in a positive or negative sense.

Studies and tests carried out in this connection have shown that:

a) the diffuser is extremely critical because the speed of the gas at the inlet pipe is very high (about 130 m/sec), while it is considerably lower at the outlet (about 3 m/sec); therefore, minimum deviations in terms of shape or minor

differences between individual parts result in substantial deviations in terms of performance;

b) the shape of the so-called "shoulder" of the belljar, i.e. the dome-shaped zone which connects the cylindrical side wall of the belljar to the neck ending in the upper flange, to which a support plate connected to the diffuser is sealingly fixed, is extremely critical because the quartz plate resting on the susceptor is situated very close to the curved wall of the said shoulder such that convective pockets are formed in the gas flow, said pockets having widely varying forms depending on the radius of curvature of said shoulder (minimum variations in this radius produce major variations in these convective pockets) and depending on the irregularities of the internal surface formed using manual glass-processing techniques. A belljar provided with a badly made dome usually results in poor results in terms of vertical uniformity, i.e. in substantial differences between one ring and the next;

c) the internal diameter of the belljar is extremely critical: if the belljar is too narrow, the uniformity on each individual wafer tends to be poor.

The abovementioned drawbacks are overcome by the present invention in which:

- a diffuser with parallel discs supplied by a central pipe according to the prior art, supported by a cap fixed to the upper flange, is replaced by a new diffuser formed by a cap supplied by a central dome-piece and connected to a symmetrical annular distribution chamber having a plurality of pipes of the same length which connects the said annular chamber of the cap to a dome zone of the belljar situated just underneath the neck connecting the upper flange to the dome, said plurality of pipes ensuring a uniform distribution of flow at a lower speed;

- the cylindrical zone of the belljar above the quartz plate supported above the susceptor is extended so as to eliminate any interference between plate and shoulder;

- a minimum internal diameter of the belljar is fixed so as to keep the belljar as far away as possible from the susceptor; and

- the corners of the susceptor, in the upper zone thereof, are provided with projecting baffles inserted into recesses formed in the body of the said susceptor,

said baffles having a length about half that of the corners of the susceptor.

The characteristic features of the present invention will be defined in the claims forming the conclusive part of the present description. However, other features and advantages of the same invention will emerge more clearly from the following detailed description of an example of embodiment thereof provided solely by way of a non-limiting illustration, and in conjunction with the accompanying drawings in which:

- Figure 1 shows a cross-sectional view of the reaction chamber of an epitaxial reactor according to the invention housing a susceptor of the type comprising two rings of seven columns each, i.e. intended for wafers with a diameter of 150 mm (6");

- Figure 2 is a sectioned plan view of the same reaction chamber along the line A-A shown in Figure 1;

- Figure 3 is a partial enlarged view of the cap and distributor assembly for the reaction chamber according to the invention; and

- Figure 4 is an exploded perspective view of the same cap and distributor assembly, showing all of its components.

With reference to the figures, it can be seen that a reaction chamber 10 of an epitaxial reactor is formed by a base 12 supporting a belljar 14 made of insulating and transparent material, such as quartz, non-reactive to the chemical reagents to be introduced into the belljar 14, and surrounded by an induction coil 16 of the reflective type, such as that illustrated in the abovementioned Italian Patent No. 1,215,444 and in the corresponding European Patent No. 293,021. Obviously, the coil 16 rests on a support 18 containing vanes 20 for distributing the air currents 22 which flow into a cavity between the belljar 14 and coil 16, performing cooling thereof.

The belljar 14 has, positioned inside it, a susceptor 24 in the form of a truncated pyramid, resting on a supporting and rotating shaft 26 and essentially formed by a lateral shell 28 made of electrically conductive material, such as graphite, and lined with a thin layer of chemically inert material, such as silicon carbide (SiC), closed at the bottom by a first flat plate 30 and at the top by a second flat plate 32. The said flat plates 30 and 32 may be made of materials

which are both insulating and inert, such as quartz or ceramic material, as well as conductive, such as graphite, provided that they are lined within inert material, such as silicon carbide. Graphite is particularly preferred because it is very easy to machine (hardness factor 2 on the Moss scale) and may be easily lined with silicon carbide using methods which have been known for a long time to skilled people in this art. The lateral shell 28 of the susceptor 24 is provided with disk-shaped cavities 34a-n able to receive wafers 36a-n of semiconductor silicon to be treated using the methods required in order to prepare semiconductor chips for integrated circuits.

The susceptor 24 has, projecting above it, a column 38 supporting a plate 40, which are both made of inert material, such as quartz or ceramic material, the plate 40 having the obvious function of preventing silicon source gases directly striking the susceptor 24.

According to the present invention, the belljar 14, instead of terminating in the usual hemispherical dome of the prior art, terminates in a shoulder 42 which is raised with respect to the susceptor 24 and the plate 40 so that the space between the belljar 14 and the plate 40 is substantially unrestricted, thereby avoiding any interference between the plate 40 and shoulder 42.

After the shoulder 42, the belljar wall continues with a flat zone 44 connected to a raised central neck 46 terminating in a thickened flange 48 which defines an opening 50 designed to receive a cap 52 of a diffuser 54 according to the invention, illustrated in greater detail in Figures 3 and 4.

The diffuser 54 consists of a hollow cap 52 connected to an annular flange 56 by means of spring-loaded tie rods 58a-c which are at least three in number and consist of knobs 60a-c, threaded shanks 62a-c, hollow sleeves 64a-c upset at the top end and threaded at the bottom, spring-pressure washers 66a-c, pressure springs 68a-c, threaded holes 70a-c for receiving the threaded areas of the sleeves 64a-c and locking screws 72a-c for fixing the said sleeves 64a-c, once screwing into the holes 70a-c has been completed. Finally, the threaded ends of the shanks 62a-c engage into threaded holes of the annular flange 56. The same flange 56 is provided with through-holes 76a-f receiving bolts 78a-f which engage into threaded holes 80a-f of two half counter-flanges 82a and 82b which, together with

the flange 56, grip the thickened flange 48 attached to the neck 46 of the belljar 14. A compensating seal 84, kept gripped by the action of the bolts 78a-f in the threaded holes 80a-f, is inserted between the counter-flanges 82a and 82b.

The cap 52 is closed at the top by a flange 86 terminating in a closed upper dome-piece 88 having, mounted above it, a threaded sleeve 90 internally engaged by a threaded shank 92 which terminates in a raising knob 94. The said dome-piece 88 communicates with a sleeve 96 for connection to an external source of gas to be used inside the reaction chamber 10. The dome-piece 88 has an internal chamber 98 with a bottom 100 defining an annular slit which, together with a further annular slit 102, provides an angularly uniform supply to an annular chamber 104 defined between the flange 86 and the upper side of the cap 52, where the annular chamber 104 communicates with outlet pipes 106a-f (in this case six in number) emerging inside the belljar 14 above the plate 40. An O-ring gasket 108 ensures a seal between the flange 86 and the cap 52 when the flange 86 is pressed against the cap 52 by a set of bolts 110a-f shown in Figures 3 and 4. The outlet pipes 106a-f, which are made of chemically inert material, such as quartz or ceramic material, are connected to the bottom of the cap 52 by means of the threaded sleeves 112a-f which are screwed into corresponding threaded holes passing through the bottom of the said cap 52. The cap 52 is provided with an internal chamber 114 for a flow of cooling fluid, such as water, which enters into and emerges from connecting sleeves 116 and 118, respectively. A sleeve 120 for connection to a space defined between two gaskets engaged between the bottom of the cap 52 and the thickened flange 48 provides an indication as to the sealing efficiency of these gaskets.

With reference again to Figures 1 and 2, it can be seen that the shell 28 and the upper flat plate 30 of the susceptor 24, in the region of the lateral corners, are provided with baffles 122a-g made of chemically inert material, such as glass, quartz, ceramic material or graphite lined with silicon carbide. Graphite is preferred since it may be easily and precisely machined and may be easily lined with silicon carbide, so that, once the desired dimensions have been achieved, the baffles 122a-g more or less require no further modification.

The silicon source gases emerge from the outlet pipes 106a-f of the

distributor 54, are diffused above the inert plate 40 and then flow between the side wall of the belljar 14 and the shell 28 of the susceptor 24 where the pyrolysis reactions occur, resulting in epitaxial deposition of silicon onto the wafers 36a-n.

The results of using the reaction chamber according to the present invention are as follows:

- 1) the individual parts are no longer of a critical nature so that, when belljars, caps and pipes are changed, the performance is unaffected;

- 2) the uniformity of thickness of individual wafers within the same batch improves;

- 3) a typical "form" for distribution of the growth thickness is obtained inside each wafer.

In particular, owing to the results 1 and 3, it has been possible to concentrate efforts solely on variations in the growth thickness inside each wafer. In fact, distribution of the thickness in each wafer occurs as follows:

in the case of a susceptor for wafers with a diameter of 125 mm (5"), having three rings of eight wafers each:

in the first ring the wafers have a growth layer which is thinner on the right-hand and left-hand sides and thicker in the centre;

in the second ring the wafers have a growth layer which is thinner on the right-hand and left-hand sides and only slightly higher in the centre;

in the third ring the wafers have a completely uniform growth layer.

In the case of a susceptor for wafers with a diameter of 150 mm (6"), having two rings of seven wafers each:

in the first ring the wafers have a growth layer which is thinner on the right-hand and left-hand sides and thicker in the centre;

in the second ring the wafers have a growth layer which is completely uniform.

The task which must be performed here is to ensure, as far as possible, an identical distribution of the growth thickness in the individual rings.

It is known that, in the barrel-type reactor, the susceptor 24 is in the form of a truncated pyramid with a regular polygonal base, while the belljar 14 has a circular shape. Consequently, the flow channel for the gases between susceptor

24 and belljar 14 has a variable cross-section in a horizontal direction with a greater cross-section in the centre of the wafer (see Figure 2 hereinbelow). Moreover, the same flow channel has a variable cross-section in the vertical direction also since the belljar 14 wall is perfectly vertical, while the side walls of the susceptor 24 are inclined by a few degrees (typically 3°) with respect to a vertical axis common to the belljar and the susceptor. This inclination results in an increase in the flow speed of the gases towards the bottom of the susceptor and the belljar, which is necessary in order to compensate for the gradual exhaustion in silicon in the mixture of hydrogen and silicon compounds which occurs as the gas flows down the susceptor. As already explained in Italian Patent No. 1,231,547 and in the corresponding published application of European Patent No. 0,415,191, a smaller cross-section corresponds, within certain limits, to a greater flow speed of the gases and therefore greater speed of silicon deposition. However, the situation is rendered more complex owing to the interaction between the boundary layers around susceptor and the belljar, where the interaction depends on the respective temperatures (it should be remembered that the susceptor 24 is heated by the currents induced by the coil 16, while the belljar is cooled by the air currents 22) and on the distance between the susceptor and internal belljar wall. For this reason, in the first ring of a susceptor for wafers with a diameter of 150 mm (6") and in the first and second rings for wafers with a diameter of 125 mm (5"), the distance between the boundary layers, and therefore the flow cross-section, is such as to produce a faster movement of the gases on the sides of the wafer than in the centre. On the other hand, in the bottom ring, the distance between the boundary layers, and therefore the flow cross-section, is such as to produce a movement of the gases with a uniform speed both on the sides and in the centre of the wafer. The problem has been solved by the measures described and claimed in the abovementioned Italian Patent No. 1,231,547 and in the corresponding published application of European Patent No. 0,415,191, the descriptions of which are regarded as incorporated herein for reference purposes. According to this solution, the corners of the susceptor have been provided with dividing baffles in order to modify the boundary layers of the upper ring without modifying the boundary layer of the bottom ring. However, as



already mentioned in the preamble of the present description, if the measure proposed by this prior art was sufficient to ensure a fairly uniform distribution in the outflow speed of the gases, moving the boundary layers away from each other, it only produced successful results so long as components extraneous to the susceptor, such as the belljar, the cap and the gas distributor with a pair of parallel superimposed disks, were not replaced. As soon as one of these components was replaced, the results became extremely negative such that the above invention was considered to be of limited value. Only now, with the discovery relating to the influence of the height of the shoulder 42 of the belljar 14 relative to the plate 40 and modification of the distributor 54, carried out as shown in detail here in Figures 3 and 4, has it been possible to eliminate the drawbacks arising in the said prior art thereby resulting in the abovementioned invention becoming fully utilisable.

As mentioned hereinabove, the present invention has made the invention described in Italian Patent No. 1,231,547 fully utilisable, together with the additional advantage of using small-size dividing baffles 122a-g which are not permanent, i.e. are simply inserted into recesses of the corners present in the susceptor 24, but are not formed integrally in the susceptor 24. The reduction in the size of the baffles 122a-g has also had positive effects on control of the resistivity of the epitaxial layer, since these baffles, being effectively heat dissipators, could influence the performance parameters, such as the uniformity of resistivity, a parameter which is sensitive to temperature, in particular at points on the wafers adjacent to the baffles. Actually, with these said smaller-size baffles 122a-g, the uniformity of resistivity does not worsen, while, owing to the improvement in the uniformity of thickness in the vertical direction, i.e. between one ring and the next, it is possible to achieve with success a temperature profile for the susceptor able to optimise this uniformity, using, for example, regulating systems involving secondary induction devices, as described in Italian Patent No. 1,215,444 and in the corresponding European Patent No. 0,293,021.

The above description relates to a particular embodiment of the invention which is not to be regarded as limiting in any way, it being possible for persons skilled in the art to devise many similar and equivalent solutions, all of which are

to be regarded as covered herein, as defined by the accompanying claims.

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## CLAIMS

1. Improved reaction chamber for an epitaxial reactor comprising a belljar (14) made of insulating and transparent material, such as quartz, a susceptor (24) provided with disk-shaped cavities (34a-n) for receiving wafers (36a-n) of material to be treated and having an insulating and chemically resistant plate (40) arranged above it, characterized by using:

a diffuser (54) formed by a cap (52) supplied by a central dome-piece (88) connected to a symmetrical annular distribution chamber (104) having a plurality of pipes (106a-f) of the same length which connect the said annular chamber (104) of the cap to a dome zone (42, 44) of the belljar situated just underneath a neck (46) connecting an upper flange (48) to the dome (42, 44), said plurality of pipes (106a-f) ensuring a uniform distribution of flow at a lower speed:

a cylindrical zone of the belljar (14) extended above the plate (40) supported above the susceptor so as to eliminate any interference between the plate (40) and shoulder (42);

a minimum internal diameter of the belljar (14) so as to keep the belljar (14) as far away as possible from the susceptor (24); and

on the corners of the susceptor (24), in its upper zone, projecting baffles (122a-g) inserted into recesses formed in the body of the said susceptor (24), said baffles (122a-g) having a length about half that of the corners of the susceptor (24).

2. Reaction chamber for an epitaxial reactor, according to Claim 1, characterized in that the cap (52) of the diffuser (54) is fixed to an annular flange (56) which is in turn fixed to the upper thickened flange (48) of the belljar (14) by means of a pair of two half counter-flanges (82a, 82b) gripping the annular flange (56) against the upper flange (48) of the belljar (14).

3. Reaction chamber for an epitaxial reactor, according to Claim 2, characterized in that fixing of the cap (52) of the diffuser (54) to the annular flange (56) is performed by means of a plurality of spring-loaded tie-rods (58a-c) which push in an elastic manner the cap (52) against the annular flange (56),

4. Reaction chamber for an epitaxial reactor, according to Claims 2 and 3, characterized in that the cap (52) is closed at the top by a flange (86)

terminating in a dome-piece (88) communicating with a sleeve (96) for connection to an external source of gas to be used in the same reaction chamber, which dome-piece is provided with a bottom (100) defining at least one circular slit for ensuring a rigorously uniform distribution of gas to an annular chamber (104) for supplying the plurality of pipes (106a-f) emerging from the distributor (54) inside the belljar (14).

5. Reaction chamber for an epitaxial reactor, according to Claim 4, characterized in that, in addition to the slit in the bottom (100), a further annular slit (102) helps ensure the uniform distribution of gas to the annular chamber (104) supplying the outlet pipes (106a-f).

6. Reaction chamber for an epitaxial reactor, according to Claims 4 and 5, characterized in that the cap (52) of the distributor (54) comprises an internal chamber (114) for the flow of a cooling fluid.

7. Reaction chamber for an epitaxial reactor, according to Claims 4, 5 and 6, characterized in that the outlet pipes (106a-f) are made of a material which is chemically inert with respect to the gas used in the belljar.

8. Reaction chamber for an epitaxial reactor, according to Claim 7, characterized in that the outlet pipes (106a-f) are made of glass.

9. Reaction chamber for an epitaxial reactor, according to Claim 7, characterized in that the outlet pipes (106a-f) are made of ceramic material.

10. Reaction chamber for an epitaxial reactor, according to Claim 7, characterized in that the outlet pipes (106a-f) are made of quartz.

11. Reaction chamber for an epitaxial reactor, according to the preceding claims, characterized in that the baffles (122a-f) fixed to the susceptor (24) are made of material chemically inert with respect to the gases used in the said chamber.

12. Reaction chamber for an epitaxial reactor, according to Claim 11, characterized in that the baffles (122a-f) fixed to the susceptor (24) are made of glass.

13. Reaction chamber for an epitaxial reactor, according to Claim 11, characterized in that the baffles (122a-f) fixed to the susceptor (24) are made of ceramic material.

14. Reaction chamber for an epitaxial reactor, according to Claim 11, characterized in that the baffles (122a-f) fixed to the susceptor (24) are made of quartz.

15. Reaction chamber for an epitaxial reactor, according to Claim 11, characterized in that the baffles (122a-f) fixed to the susceptor (24) are made of graphite lined with silicon carbide.



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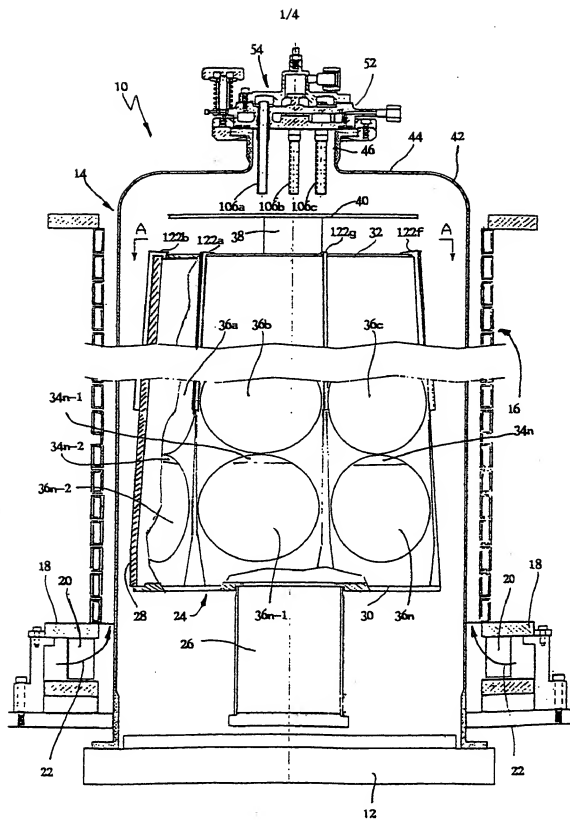


FIG. 1

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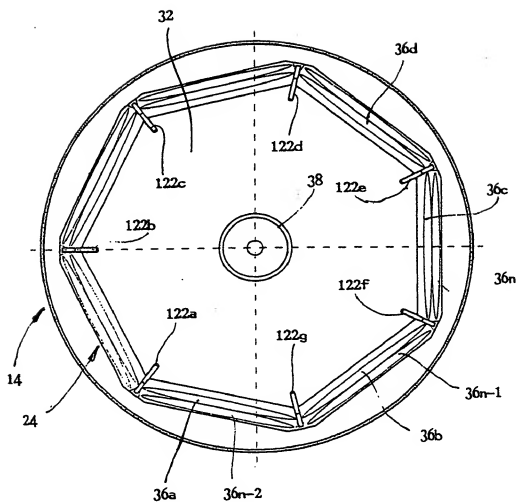


FIG. 2

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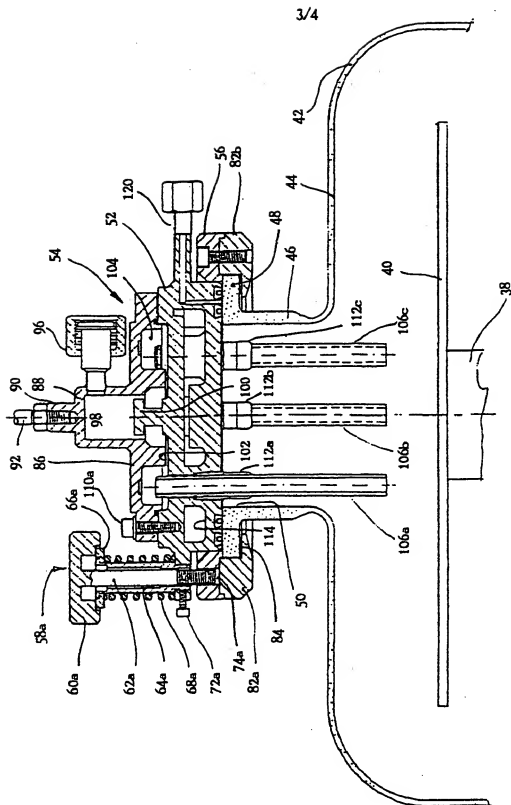
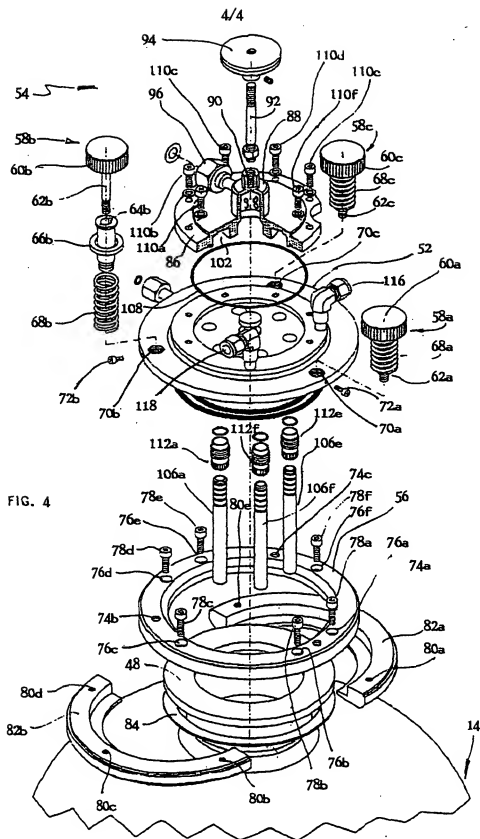


FIG. 3

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